Observatory Test & Calibration Approach
Instrument Control & Data

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Overview

- **The Preliminary Test and Calibration Approach As Outlined:**
  - **Primarily Addresses Instrument Control and Data Flow**
  - **Identifies the Test and Calibration Opportunities From Component Test Through Flight Operations**
  - **Lists the Set of Test and Calibration Activities**
  - **Correlates the Test and Calibration Activities With the Available Opportunities and Required Configurations**

- **The Ongoing Test and Calibration Approach Refinement Effort Will Be Used to:**
  - **Evaluate Test Coverage**
    - **Ensure Adequate Coverage, While Reducing Unnecessary Duplication**
  - **Evaluate Calibration Data Collection**
    - **Ensure Adequate Coverage and Provide Consistent Data Collection and Reporting**
  - **Refine GSE and Test/Calibration Software Support Requirements**
  - **Refine NRL, LM ATC and USNO Organizational Responsibilities With Respect to Test and Calibration**
  - **Ensure Proper Flow Down of Test and Calibration Requirements to Applicable Component, Subsystem, System and Operational Test Plans**

Test and Calibration Phases

- **Instrument Standalone**
- **Bus Command, Telemetry and Data Handling (CTDH) Standalone**
- **Integrated Instrument/CTDH**
- **Integrated Observatory**
- **Pre-Launch**
- **GTO**
- **Observatory EE&C**
- **Observatory Operations**

Instrument Standalone

- **Description: Instrument Design Validation, Functional Validation, Environmental Qualification and Calibration**
- **Responsibility: LM ATC**
- **Configuration: Instrument and LM ATC GSE**
- **Test/Calibration Sub-Phases:**
  - **Single CCD**
  - **Engineering Model Focal Plane Assembly**
  - **Flight Model Focal Plane Assembly**
  - **Instrument Integration (Ambient)**
  - **Instrument Test (Environmental)**
  - **Instrument Ship Preparation**
  - **Instrument Post-Ship**

Bus Command, Telemetry & Data Handling (CTDH) Standalone

- Description: CTDH Hardware and Software Design Validation, Functional Validation and Environmental Qualification
- Responsibility: NRL
- Configuration: CTDH and NRL GSE
- Test/Calibration Sub-Phases:
  - CTDH HW
    - Board Level
    - Engineering Model
    - Flight Model
  - Flight Software
    - Unit
    - Software Integration
    - FSW System - Software Only Test Bed (SOTB)
  - Integrated CTDH/FSW
    - HW/SW Integration
    - HW Acceptance (Environmental)
    - FSW Acceptance

Integrated Instrument/CTDH

- **Description: Instrument Integration With the CTDH Hardware and Software at LM ATC**
- **Responsibility: NRL/LM ATC (Details TBD)**
- **Configuration: Instrument, LM ATC GSE, CTDH and NRL GSE**
- **Test/Calibration Sub-Phases:**
  - **Engineering Model FPA**
  - **Flight Model FPA**
  - **Instrument Test (Environmental)**

Integrated Observatory

- **Description: Instrument Integrated With the FAME Bus at NRL**
- **Responsibility: NRL W/ LM AATC Support**
- **Configuration: Integrated Observatory, NRL GSE**
- **Test/Calibration Sub-Phases:**
  - **Integration (Ambient)**
  - **Acceptance (Functional, Performance and Environmental)**
  - **Pre-Ship**

Pre-Launch

- **Description: Observatory Launch Preparation at Launch Site**
- **Responsibility: NRL W/ LM ATC Support**
- **Configuration: Observatory**
- **Test/Calibration Sub-Phases:**
  - **Post-Ship Functional**
  - **Maintenance/Monitoring Prior to Launch Vehicle Integration**
  - **Pre-Launch Readiness (Integrated Observatory/Launch Vehicle)**

Geo-Synchronous Transfer Orbit (GTO)

- **Description: Instrument Activities While in GTO**
- **Responsibility: MOC/SOC**
- **Configuration: Observatory**
- **Test/Calibration Sub-Phases:**
  - **TBD**

Observatory EE&C

- **Description: Observatory Engineering, Evaluation and Checkout**
- **Responsibility: MOC/SOC**
- **Configuration: Observatory**
- **Test/Calibration Sub-Phases:**
  - **Prior to Mission Attitude and Rates**
  - **Mission Attitude and Rate Determination and Control**
  - **At Mission Attitude and Rates**

Observatory Operations

- **Description: Observatory Science Operations**
- **Responsibility: MOC/SOC**
- **Configuration: Observatory**
- **Test/Calibration Sub-Phases:**
  - **Continual Science and Engineering Data Collection**
  - **Periodic Engineering Data Collection**

Test and Calibration Summary

Tests Must Meet Acceptance Criteria
Calibrations Must Meet Data Collection Criteria

- Instrument Timing Interface
- Instrument Command Interface
  - Discretes
  - TDI Rate
  - Focus Control
  - LED Point
  - LED Flood
  - Heater Control
- Telemetry Interface
  - Temperature Sensors
- Instrument Control Interface
  - Window
  - Charge Injection
  - Virtual Frame Timing
  - Diagnostics
- CCD Data Acquisition
  - Dark Noise
  - Flood (Flat Field) - LED
  - Flood (Flat Field) - External Source (Sphere)
  - Point Source Sweep
  - Point Source Pattern Flash
- Instrument Actuators
  - Focus Adjust - LED
  - Focus Adjust - Point Source
  - Focus Adjust - Star
- Observatory Functions
  - Coarse Attitude/rate Determination
  - Coarse Attitude Control Modes
  - Coarse Balance & Trim
  - Initial Acquisition
  - Subsequent Acquisition
  - Fine Attitude/rate Determination
  - Fine Attitude/rate Control
  - Fine Balance & Trim
  - Fine Attitude/rate Propagation
  - Science Data Collection
  - Star Catalog Maintenance

Test/Calibration Objectives vs Phase

	Instrument Timing Interface	Clock Signals	Instrument Command Interface	Discretes	Focus Control	LED Point	LED Flood	Heater Control	Telemetry Interface	Temperature Sensors	Instrument Control Interface	Window	Charge Injection	TDI Rate	Diagnostics	CCD Data Acquisition	Dark Noise	Flood (flat field) - LED	Flood (flat field) - External source (sphere)	Point Source Sweep	Point source pattern flash	Instrument Actuators	Focus Adjust - LED	Focus Adjust - Point Source	Focus Adjust - Star	Observatory Functions	Coarse Attitude/Rate Determination	Coarse Attitude Control Modes	Coarse Balance & Trim	Initial Acquisition	Subsequent Acquisition	Fine Attitude/Rate Determination	Fine Attitude/Rate Control	Fine Balance & Trim	Fine Attitude/Rate Propagation	Science Data Collection	Star Catalog Maintenance
Test Phases																																				
Instrument Standalone																																				
Single CCD																	X		X																	
Engineering Model Focal Plane Assembly		X		X								X	X	X	X				X																
Flight Model Focal Plane Assembly		X		X								X	X	X	X				X																
Instrument Integration (Ambient)		X		X	X	X	X	X		X		X	X	X	X			X					X	X											
Instrument Test (Environmental)		X		X	X	X	X	X		X		X	X	X	X		X		X		X		X	X											
Instrument Ship Preparation		X		X	X	X	X	X		X		X	X	X	X								X												
Instrument Post-Ship		X		X	X	X	X	X		X		X	X	X	X								X												
Bus Command, Telemetry & Data Handling (CTDH) Standalone																																				
CTDH HW																																				
Board Level												X	X	X	X																					
Engineering Model												X	X	X	X												X	X		X	X	X	X		X	X	X
Flight Model												X	X	X	X												X	X		X	X	X	X		X	X	X
Flight Software																																				
Unit												X	X	X	X												X										
Software Integration												X	X	X	X												X										
FSW System - Software Only Test Bed (SOTB)				X	X	X	X	X		X		X	X	X	X												X										
Integrated CTDH/FSW																																				
HW/SW Integration				X	X	X	X	X		X		X	X	X	X												X	X		X	X	X	X			X	X
HW Acceptance (environmental)												X	X	X	X													X	X					X			X
FSW Acceptance				X	X	X	X	X		X		X	X	X	X												X	X		X	X	X	X		X	X	X
Integrated Instrument/CTDH																																				
Engineering Model FPA		X										X	X	X	X		X	X					X													
Flight Model FPA		X										X	X	X	X		X	X					X													
Instrument Test (Environmental)		X								X		X	X	X	X		X	X	X		X		X													
Integrated Observatory																																				
Integration (ambient)				X	X	X	X	X		X		X	X	X	X		X	X			X		X													
Acceptance (Functional, Performance & Environmental)				X	X	X	X	X		X		X	X	X	X		X	X			X		X						X					X		
Pre-Ship				X	X	X	X	X		X		X	X	X	X			X			X		X													
Pre-Launch																																				
Post-Ship Functional				X	X	X	X	X		X		X	X	X	X		X	X			X		X													
Maintenance/Monitoring prior to launch vehicle integration				X						X							X	X			X		X													
Pre-launch readiness (integrated Observatory/Launch Vehicle				X				X		X							X	X			X		X													
GTO																																				
TBD				X	X	X	X	X		X		X	X	X	X		X	X			X		X				X	X								
Observatory EE&C																																				
Prior to mission attitude & rates				X	X	X	X	X		X		X	X	X	X		X	X			X		X				X	X								
Mission attitude & rate determination and control				X	X	X	X	X		X		X	X	X	X		X	X			X		X				X	X	X	X						
At mission attitude & rates				X	X	X	X	X		X		X	X	X	X		X	X			X		X		X		X	X	X	X	X	X	X	X	X	X
Observatory Operations																																				
Continual science and engineering data collection								X		X		X	X	X	X		X								X		X				X	X	X	X	X	X	X
Periodic engineering data collection						X	X	X		X		X	X	X	X			X					X		X												

Test/Calibration Objectives vs. Flight Equipment, GSE and Interfaces

		Instrument Timing Interface	Clock Signals	Instrument Command Interface	Discretes	Focus Control	LED Point	LED Flood	Heater Control	Telemetry Interface	Temperature Sensors	Instrument Control Interface	Window	Charge Injection	TDI Rate	Diagnostics	CCD Data Acquisition	Dark Noise	Flood (flat field) - LED	Flood (flat field) - External source (sphere)	Point Source Sweep	Point source pattern flash	Instrument Actuators	Focus Adjust - LED	Focus Adjust - Point Source	Focus Adjust - Star	Observatory Functions	Coarse Attitude/Rate Determination	Coarse Attitude Control Modes	Coarse Balance & Trim	Initial Acquisition	Subsequent Acquisition	Fine Attitude/Rate Determination	Fine Attitude/Rate Control	Fine Balance & Trim	Fine Attitude/Rate Propagation	Science Data Collection	Star Catalog Maintenance
Flight Equipment																																						
	Bus/NRL																																					
	FSC - Breadboard				X	X	X	X	X		X		X	X	X	X		X	X			X		X	X			X	X	X	X	X	X	X	X	X	X	X
	FSC - Flight				X	X	X	X	X		X		X	X	X	X		X	X			X		X		X		X	X	X	X	X	X	X	X	X	X	X
	RIU				X	X	X	X	X		X													X	X	X												
	IMU																											X	X	X	X	X						
	Star Tracker																											X	X	X	X	X						
	Sun Angle Sensor																																					
	Magnetometer																													X	X	X		X				
	Torque Rod																																	X				
	Thruster Valve Relays																												X	X								
	Instrument/LM ATC																																					
	CCD Standalone - Engineering				X													X	X	X		X																
	CCD Standalone - Flight				X													X	X	X		X																
	FPA - Engineering		X		X								X	X	X	X		X	X	X		X																
	FPA - Flight		X		X						X		X	X	X	X		X	X	X		X																
	Instrument		X		X	X	X	X	X		X		X	X	X	X		X	X	X		X		X	X	X												
GSE & Test Environment																																						
	NRL																																					
	SW Only Test Bed (SOTB)												X	X	X	X												X	X		X	X	X	X		X	X	X
	FSC Test Bed (FTB) - Ambient																																					
	FSC Test Bed (FTB) - Environmental																																					
	SW Test Bed (STB)												X	X	X	X								X				X	X	X	X	X	X	X	X	X	X	X
	EAGE - Ambient												X	X	X	X		X	X			X		X				X	X	X	X	X	X	X	X	X	X	X
	EAGE - Ambient/Clean												X	X	X	X		X	X			X		X														
	EAGE - Environmental												X	X	X	X		X	X			X		X				X	X	X	X	X	X	X	X	X	X	X
	LM ATC																																					
	CCD Test Bed																	X	X	X		X																
	Instrument Test GSE - Ambient		X		X	X	X	X	X				X	X	X	X		X	X	X		X		X														
	Instrument Test GSE - Environmental		X		X	X	X	X	X				X	X	X	X		X	X	X		X		X														
	Optical Test Bed - Ambient												X	X	X	X		X	X	X		X		X	X													
	Optical Test Bed - Environmental												X	X	X	X		X	X	X		X		X	X													
Interfaces																																						
	Instrument Time Signals		X										X	X	X	X		X	X	X		X		X	X	X					X	X	X				X	
	CCX/AP IF Controller Control		X										X	X	X	X		X	X	X		X		X	X	X					X	X	X				X	
	CCX/AP IF Controller Binned Data												X	X	X	X		X	X	X		X		X	X	X							X				X	
	CCX/AP IF Controller Unbinned/Eng Data												X	X	X	X		X	X	X		X		X	X	X					X	X	X				X	
	Instrument Serial Command					X	X	X	X															X	X	X					X	X	X				X	
	Instrument Serial Telemetry																														X	X	X				X	
	Instrument HW Command				X																										X	X	X				X	
	Instrument HW Telemetry										X																				X	X	X				X	
	FSC Return Link				X	X	X	X	X		X		X	X	X	X		X	X	X	X	X		X	X	X		X			X	X	X	X	X		X	X
	FSC Command Link				X	X	X	X	X				X	X	X	X		X	X	X	X	X		X	X	X		X	X		X	X	X	X	X		X	X
	RIU (1553 Bus)				X	X	X	X	X		X													X	X	X		X	X	X	X	X	X	X	X		X	
	Star Tracker (1553 Bus)																											X			X	X						
	IMU																											X			X	X						
	Sun Sensor																											X										
	Thruster Valve Relay																												X									

Test/Calibration Objectives vs. Instrument Optical Configuration, Modes and Commands

			Instrument Timing Interface		Instrument Command Interface						Telemetry Interface		Instrument Control Interface					CCD Data Acquisition							Instrument Actuators				Observatory Functions														
				Clock Signals		Discretes	Focus Control	LED Point	LED Flood	Heater Control		Temperature Sensors		Window	Charge Injection	TDI Rate	Diagnostics		Dark Noise	Flood (flat field) - LED	Flood (flat field) - External source (sphere)	Point Source Sweep	Point source pattern flash		Focus Adjust - LED	Focus Adjust - Point Source	Focus Adjust - Star		Coarse Attitude/Rate Determination	Coarse Attitude Control Modes	Coarse Balance & Trim	Initial Acquisition	Subsequent Acquisition	Fine Attitude/Rate Determination	Fine Attitude/Rate Control	Fine Balance & Trim	Fine Attitude/Rate Propagation	Science Data Collection	Star Catalog Maintenance
Optical Source																																										
	Dark Field													X	X	X	X		X																							
	Internal Point Source LED						X	X						X	X	X	X						X																			
	Internal Flood LED								X					X	X	X	X			X																						
	External Point Source						X							X	X	X	X																									
	External Flood Source													X	X	X	X				X																					
	External Pattern													X	X	X	X																									
	Star Field													X	X	X	X																									
Optical Configuration																																										
	CCD Standalone - Ambient													X	X	X	X		X		X																					
	CCD Standalone - Cold													X	X	X	X		X		X																					
	CCD FPA - Ambient													X	X	X	X		X		X																					
	CCD FPA - Cold													X	X	X	X		X		X																					
	Instrument - Ambient					X	X	X	X	X		X		X	X	X	X		X	X	X		X		X	X																
	Instrument - Cold					X	X	X	X	X		X		X	X	X	X		X	X	X		X		X	X	X		X					X	X	X					X	
Instrument Mode																																										
	1d/2d							X						X	X	X	X						X		X	X							X							X	
	2d/Raw							X	X					X	X	X	X		X	X	X				X	X	X														
Instrument Commands																																										
	Window - Normal							X	X					X					X	X	X		X		X	X	X							X	X	X					X	
	Window - Extended Pixel													X					X	X	X																				
	Window - Overscan													X					X	X	X																				
	Charge Injection														X												X													X	
	Fat 0																X		X																						
	TDI Rate			X				X	X							X			X	X	X		X		X	X	X							X	X	X					X	
	Focus LED							X																	X																
	Flood LED								X											X																					
	Focus Actuator						X																X		X	X	X														
Test Data Consumer																																										
	LM ATC				X		X	X	X	X		X		X	X	X	X		X	X	X		X		X	X	X							X	X	X					X	
	USNO				X		X	X	X					X	X	X	X		X	X	X		X		X	X	X							X	X	X					X	
	NRL				X		X	X	X	X		X		X	X	X	X		X	X			X											X	X	X					X	

Actions

- **Refine and Expand Details of Observatory Test Approach**
  - **NRL/LM ATC/USNO**
- **Reach Agreement on NRL CT&DH Integration/Test Support Oportunities and Requirements at LM ATC**
  - **NRL/LM ATC**
- **Define Programmatic Responsibilities and Coordination Requirements for Those Tests That Will Involve Integrated Bus and Instrument Elements (Both at LM ATC and at NRL)**
  - **NRL/LM ATC**
- **Define Instrument Component and Integrated Test Data Collection Requirements and Data Formats for LM ATC, USNO and NRL**

Backup

Instrument Timing Interface

- **Tests: Verify Clock Stability and Timing Distribution**
- **Calibration: Characterize Clock Stability**
- **Interfaces Utilized: Instrument Command, Instrument Clock, Line Synch, Frame Synch, Time Synchronization Epoch**
- **Stimulus Range: Vary TDI Rate, Vary Temperature**
- **Data Acquisition: High Precision Measurement of Timing Signals, Collect Over Period Necessary to Measure Stability**
- **Acceptance Criteria:**
  - **Verify Waveforms**
  - **Verify Rates**
  - **Verify Stability**
  - **Verify Signal Timing Correlation**

Instrument Command Interface

- **Tests: Verify Proper Response to Commands, Verify Command Interface Integrity**
- **Calibration: As Required Per Control (TBD)**
- **Interfaces Utilized: Instrument Command and As Needed Per Control (i.e. Line Synch, Frame Sync for TDI Rate)**
- **Stimulus Range:**
  - **Appropriate Valid Commands and Parameter Ranges**
  - **Invalid Commands and Parameters**
- **Data Acquisition: As Required Per Control (TBD)**
- **Acceptance Criteria:**
  - **Verify Proper Response Per Control Request (TBD Per Control)**

Instrument Control Interface - Window

- Tests: Verify Proper Instrument Response to the Window and Window Size Commands
- Calibration: None
- Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/Engineering Data IF)
- Stimulus Range:
  - Vary TDI Rate
  - Vary Mode (Science, Acquisition, Engineering)
  - Vary CCD Half
  - Vary Window Size
  - Vary Window Size Selection
  - Vary Number of Window Command Per CCD Half
  - Vary Binning
  - Vary Gain
  - Vary Window Position (Absolute to Virtual Frame and Relative to Other Windows)
  - Introduce Invalid Window Size Selections and Window Requests
- Data Acquisition: All Resulting Binned and Unbinned/engineering Interface Data
- Acceptance Criteria:
  - Verify Proper Data Production
  - Verify Proper Window Alignment
  - Verify Proper Response to Invalid Requests

Instrument Control Interface - Charge Injection

- Tests: Verify Proper Instrument Response to the Charge Injection Command
- Calibration: CCD Response (All CCDs All Columns) to Profiles, Charge Amplitudes,
- Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/engineering Data IF)
- Stimulus Range:
  - Vary TDI Rate
  - Vary Mode (Science, Acquisition, Engineering)
  - Vary CCD Half
  - Vary Profile
  - Vary Charge Amplitude
  - Vary Number of Window Command Per CCD Half
  - Vary Charge Injection Position (Absolute to Virtual Frame and Relative to Other Windows)
  - Introduce Invalid Charge Injection Requests
- Data Acquisition: Collect Charge Injection Response With the Use of Overlapping Windows
- Acceptance Criteria:
  - Verify Proper CCD Pixel Value Response
  - Verify Proper Charge Injection Segment Alignment
  - Verify Proper Response to Invalid Requests

Instrument Control Interface - Virtual Frame Timing

- Tests: Verify Proper Instrument Response to the Frame Delay Commands
- Calibration: None
- Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/Engineering Data IF)
- Stimulus Range:
  - Use Synchronized (to Frame Synch/line Sync) Internal or External Flashed Point Source
  - Maintain Constant Frame Delay for a TBD Period
  - Vary Frame Delay
  - Introduce Invalid Frame Delay Requests
- Data Acquisition: Binned and Unbinned/Engineering IF Data and Timing Signals
- Acceptance Criteria:
  - Verify Proper Position of Captured Flashed Point Source Data
  - Confirm Proper Relationship Between Frame Synch Signal With CCX/AP IF Controller Data Output Signals and CTS Signal
  - Verify Proper Response to Invalid Requests

Instrument Control Interface - Diagnostics

- **Tests: Verify Proper Instrument Response to the Diagnostic Commands**
- **Calibration: None**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Exercise Valid Diagnostic Commands**
  - **Exercise Invalid Diagnostic Commands**
- **Data Acquisition: All Resulting Binned and Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify Proper Data Production**
  - **Verify Proper Response to Invalid Requests**

CCD Data Acquisition - Dark Noise

- **Tests: Verify Proper Production of Dark Noise by CCDs**
- **Calibration: Measure CCD Dark Noise**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Measure All Columns of All CCDs**
- **Data Acquisition: All Resulting Binned and Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify Proper Dark Noise CCD Response**

CCD Data Acquisition - Flood (Flat Field) - LED

- **Tests: Use the Internal Instrument Flat Field LED to Flood the CCD, Collect and Verify the Response**
- **Calibration: Measure CCD Response to a Flashed Flat Field Light Source**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Flash Source Duration (Intensity) - Duration Must Be Less Than a Row Interval and Occur Between Line Synchs**
  - **Collect All Columns From All CCDs**
    - **Collect a Consecutive Set of 4096 Rows Per Column**
    - **The 4096 Rows That Are Collected Must Represent the Collection of Pixels Exposed to the Flat Field Source (I.E. Likely Approach Is to Synchronize Flash With the Frame Synch)**
  - **Multiple Windows Per CCD Half From Different Virtual Frames Will Need to Be Collected to Sample All Pixels From a CCD Half**
- **Data Acquisition: All Resulting Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify Proper CCD Response to a Flashed Flat Field Light Source**

CCD Data Acquisition - Flood (Flat Field) - External Source (Sphere)

- Tests: Use and External Light Source (Sphere) to Flood the CCD, Collect and Verify the Response
- Calibration: Measure CCD Response to a Flashed Flat Field Light Source
- Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF)
- Stimulus Range:
  - Vary TDI Rate
  - Vary Flash Source Duration (Intensity) - Duration Must Be Less Than a Row Interval and Occur Between Line Synchs
  - Vary Flash Source Frequency (Utilize Various Filters)
  - Collect All Columns From All CCDs
    - Collect a consecutive set of 4096 rows per column
    - The 4096 Rows That Are Collected Must Represent the Collection of Pixels Exposed to the Flat Field Source (I.E. Likely Approach Is to Synchronize Flash With the Frame Synch)
  - Multiple Windows Per CCD Half From Different Virtual Frames Will Need to Be Collected to Sample All Pixels From a CCD Half
- Data Acquisition: All Resulting Unbinned/engineering Interface Data
- Acceptance Criteria:
  - Verify Proper CCD Response to a Flashed Flat Field Light Source

CCD Data Acquisition - Point Source Sweep

- **Tests: Verify Proper Charge Transfer of a Synchronized Sweeping Point Source**
- **Calibration: Measure Point Spread Function of a Sweeping Point Source**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Light Intensity**
  - **Vary Light Frequency**
  - **Introduce Varying Amounts of Cross-scan and In-scan Smearing**
  - **Cover All CCDs and a Representative Set of Columns**
- **Data Acquisition: All Resulting Binned and Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify Proper CCD Response to a Sweeping Point Source Synchronized to the TDI Rate**

CCD Data Acquisition - Point Source Pattern Flash

- **Tests: Verify Proper Data Production and Alignment From a Flashed Point Source Pattern**
- **Calibration: Measure Relative Position of Point Sources Over Difference Areas of the FPA**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Binned and Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Flash Source Duration Must Be Less Than a Row Interval and Occur Between Line Synchs**
  - **Vary the Duration (or Intensity) of the Flash**
  - **Vary the Wavelengths of the Flash Source (Filter the Flash Source)**
  - **Collect Data From All CCDs**
    - **Move Pattern Over Representative Area of Each CCD**
  - **Collect Binned and Unbinned Science Windows of the Pattern (Is Engineering Data Required ?)**
  - **Flash Synchronization Will Likely Be Relative to the Instrument Frame Synch Pulse**
- **Data Acquisition: All Resulting Binned and Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify Proper Data Collection of the Pattern (SW Test Only ?)**

Instrument Actuators - Focus Adjust - LED

- **Tests: Verify Ability to Focus Using a Flash From the Instrument Focus LED**
- **Calibration:**
  - **Measure Response of the CCDs to a Flashed Focus LED**
  - **Measure Response of the CCDs to the Varying Position and Orientation of the Moveable Optical Element**
  - **Measure Focus at Various Points Associated With Instrument Integration, Test, Transport and Post Launch Activities**
- **Interfaces Utilized: Instrument Command (TDI Rate, Focus Actuators), CCX/AP If Controller (Control If), CCX/AP If Controller (Unbinned/Engineering Data If)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Position of the Optical Element Using the Focus Actuators**
  - **Flash Source Duration Must Be Less Than a Row Interval and Occur Between Line Synchs**
  - **Flash Synchronization Will Likely Be Relative to the Instrument Frame Synch Pulse**
  - **Collect Engineering Windows From the CCD Half and Location Exposed to the Focus LED**
- **Data Acquisition: All Resulting Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify the Instrument Can Be Focused Using the Instrument Focus LED**

Instrument Actuators - Focus Adjust - Point Source

- **Tests:**
  - **Verify Ability to Focus Using a Flash From an External Point Source**
- **Calibration:**
  - **Measure Response of the CCDs to a Flashed External Point Source**
  - **Measure Response of the CCDs to the Varying Position and Orientation of the Moveable Optical Element**
  - **Measure Response of the CCDs to the Varying Position of the Point Source Over the FPA**
- **Interfaces Utilized:**
  - **Instrument Command (TDI Rate, Focus Actuators), CCX/AP If Controller (Control If), CCX/AP If Controller (Unbinned/Engineering Data If)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Position of the Optical Element Using the Focus Actuators**
  - **Flash Source Duration Must Be Less Than a Row Interval and Occur Between Line Synchs**
  - **Flash Synchronization Will Likely Be Relative to the Instrument Frame Synch Pulse**
  - **Vary the Position of the Point Source Over All CCDs and a Representative Area on All CCDs**
  - **Collect Engineering Windows Encompassing the Position of the External Point Source**
- **Data Acquisition:**
  - **All Resulting Unbinned/Engineering Interface Data**
- **Acceptance Criteria:**
  - **Verify the Instrument Can Be Focused Using an External Point Source**

Instrument Actuators - Focus Adjust - Star

- **Tests: None**
- **Calibration: Collect Star Data for the Purposes of Focusing the Instrument**
- **Interfaces Utilized: Instrument Command (TDI Rate, Focus Motor), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Collect Unbinned Data From Various Stars and Positions on the FPA**
- **Data Acquisition: All Resulting Unbinned/Engineering Interface Data**
- **Acceptance Criteria: N/A**

Observatory Functions - Coarse Attitude/Rate Determination

- **Tests:**
  - **Verify Hardware Interfaces to the Attitude Sensors (Star Trackers, IMUs and Sun Angle Sensors) Are Working Properly**
  - **Verify Proper Software Collection of Sensor Data**
  - **Verify Observatory Attitude and Rates Are Correctly Determined**
- **Calibration: None**
- **Interfaces Utilized:**
  - **Attitude Sensor Control and Data**
  - **Command and Telemetry**
- **Stimulus Range:**
  - **Inject a Representative Set of Scenario Generated Sensor Data**
  - **Vary Simulated Sensor Data to Cover a Representative Set of Attitudes/rates**
  - **Inject Representative Set of Bad Sensor Data (I.E. Subject FSW to Sensor Failures)**
  - **Expose CT&DH HW & SW to Flight (and Engineering ?) Sensor Data**
- **Data Acquisition: Spacecraft Telemetry Indicating Sensor Interface Status and Spacecraft Attitude**
- **Acceptance Criteria:**
  - **Confirm Proper Interface Behavior Over Long Periods of Time**
  - **Compare Flight Software Calculated Attitude and Rates to Injected Simulated Data**
  - **Verify Proper Response of Flight Software to Invalid Sensor Data**
  - **Verify Proper Response of Flight Software to Flight (and Engineering ?) Sensor Data**

Observatory Functions - Coarse Attitude Control Modes

- **Tests:**
  - **Verify Hardware Interfaces to the Attitude Control Actuators (Thruster Valve Relay Drivers) Are Working Properly**
  - **Verify Proper Operation of SW/HW Interface to the Attitude Control Actuators**
  - **Verify Observatory Attitude and Rates Are Controlled in All Modes (Inertial Pointing, Spin Rate Control, Spin Axis Precession, Auto-Nutation Control)**
- **Calibration: None**
- **Interfaces Utilized:**
  - **Attitude Sensor Control and Data**
  - **Command and Telemetry**
  - **Attitude Control Actuator Interfaces**
- **Stimulus Range:**
  - **Inject a Representative Set of Scenario Generated Sensor Data.**
  - **Vary Simulated Sensor Data to Cover a Representative Set of Attitudes/rates.**
  - **Expose Ct&dh HW & SW to Flight (and Engineering ?) Sensor Data - Open Loop**
  - **Coordinate Attitude Control Requests With Simulated or Actual Data - Open Loop**
  - **Send Attitude Control Requests - Closed Loop**
- **Data Acquisition:**
  - **Spacecraft Telemetry Indicating Sensor and Actuator Interface Status, Spacecraft Attitude and Attitude Control Status**
  - **Collect Data From Actuator Interface (i.e. Thruster Firings)**
- **Acceptance Criteria:**
  - **While in Open Loop Mode, Confirm Proper Actuator Activity in Response to Requested Attitude Control Mode and Parameters**
  - **While in Closed Loop Mode, Confirm Proper Attitude Is Maintained**

Observatory Functions - Coarse Balance & Trim

- **Tests: Verify Hardware and Software Interfaces to the Balance (Mass) and Trim (Area & Tabs) Actuators Are Working Properly**
- **Calibration: Collect Attitude and Rate Responses to Balance and Trim Device Movement**
- **Interfaces Utilized:**
  - **Attitude Sensor Control and Data**
  - **Command and Telemetry**
- **Stimulus Range:**
  - **Exercise Full Range of Balance and Trim Actuators in a Ground Test Environment**
  - **Use Coarse Attitude and Rate Information to Perform Coarse (Initial) Balance and Trim Functions on Orbit**
- **Data Acquisition: Spacecraft Telemetry Indicating Actuator Interface Status and Spacecraft Attitude**
- **Acceptance Criteria: Confirm Proper Interface Behavior Over Long Periods of Time**

Observatory Functions - Initial Acquisition

- **Tests:**
  - **Capture Acquisition Star Image From the Instrument**
  - **Determine Attitude From Acquisition Star Location in the Acquisition Image**
- **Calibration: Bore Sight Alignment Between the Star Trackers and the Instrument FOVs**
- **Interfaces Utilized: Attitude Sensor Control and Data**
  - **Command and Telemetry**
  - **Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Flash Point Source Timing and Position (i.e. Location in or Out of Acquisition Window)**
  - **Vary Charge Injection Profile, Amplitude, Repetition and Timing (I.E. Location) to Simulate Cross-Scan and In-Scan Smearing of the Acquisition Star**
  - **Introduce Multiple Acquisition Stars**
- **Data Acquisition:**
  - **All Resulting Unbinned/Engineering Interface Data**
  - **Ground Processing Data Indicating Status of Initial Acquisition Function and the Resulting Attitude and Rates**
- **Acceptance Criteria: Confirm Acquisition (i.e. Attitude Determination) Solution Is Within the Acceptable Accuracy Range**
- ***Note: Initial Acquisition May Require a Search Mode. Initial Acquisition Function May Be Performed by a Ground SW Function***

Observatory Functions - Subsequent Acquisition

- **Tests: Capture Acquisition Star Image From the Instrument. Determine Attitude From Acquisition Star Location in the Acquisition Image**
- **Calibration: Identify Bore Sight Alignment Stability Between the Star Trackers and the Instrument FOVs**
- **Interfaces Utilized: Attitude Sensor Control and Data. Command and Telemetry. Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Flash Point Source Timing and Position (i.e. Location in or Out of Acquisition Window)**
  - **Vary Charge Injection Profile, Amplitude, Repetition and Timing (I.E. Location) to Simulate Cross-scan and In-scan Smearing of the Acquisition Star.**
  - **Introduce Multiple Acquisition Stars**
- **Data Acquisition: All Resulting Unbinned/Engineering Interface Data. Spacecraft Telemetry Data Indicating Status of Acquisition Function and the Resulting Attitude and Rates**
- **Acceptance Criteria: Confirm Acquisition (i.e. Attitude Determination) Solution Is Within the Acceptable Accuracy Range and Performed Within the Required Time Period**
- ***Note: Subsequent Acquisition Is Intended to Be Performed Without Searching. The Subsequent Acquisition Function May Be Performed by the On-board Flight SW***

Observatory Functions - Fine Attitude/Rate Determination

- **Tests: Verify Observatory Attitude and Rates Are Correctly Determined Based on Guide Star Tracking**
- **Calibration: Characterize Spacecraft Stability**
- **Interfaces Utilized: Command and Telemetry. Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF)**
- **Stimulus Range:**
  - **Vary TDI Rate**
  - **Vary Flash Point Source Timing and Position (i.e. Location in or Out of Unbinned Guide Star Window)**
  - **Vary Charge Injection Profile, Amplitude, Repetition and Timing (i.e. Location) to Simulate Cross-scan and In-scan Smearing of the Guide Star.**
  - **Introduce Multiple Guide Stars**
- **Data Acquisition: All Resulting Unbinned/Engineering Interface Data. Spacecraft Telemetry Data Indicating Status of Tracking Function and the Resulting Attitude and Rates**
- **Acceptance Criteria: Confirm Attitude and Rate Solutions Are Within the Acceptable Accuracy Range**

Observatory Functions - Fine Attitude/Rate Control

- **Tests:**
  - **Verify Hardware Interfaces to the Fine Attitude Control Sensors (Magnetometers) Are Working Properly**
  - **Verify Proper Software Collection of Sensor Data**
  - **Verify Observatory Attitude and Rates Are Correctly Controlled Using Torque Rods**
- **Calibration: Magnetometer Response to Earth's Magnetic Field and the Spacecraft Response to Torque Rod Use**
- **Interfaces Utilized:**
  - **Magnetometer Sensor Data**
  - **Torque Rod Control**
  - **Command and Telemetry**
- **Stimulus Range:**
  - **Vary Rate Correction Request Parameters (Calculated or Uplinked)**
  - **Inject a Representative Set of Scenario Generated Magnetometer Data**
  - **Vary Simulated Magnetometer Data to Cover a Representative Set of Attitudes/Rates**
  - **Inject Representative Set of Bad Magnetometer Data (i.e. Subject FSW to Sensor Failures)**
  - **Coordinate Attitude Control Requests With Simulated or Actual Data - Open Loop**
  - **Send Attitude Control Requests - Closed Loop**
- **Data Acquisition: Spacecraft Telemetry Indicating Magnetometer and Torque Rode Interface Status, Spacecraft Attitude and Attitude Control Status. Collect Control Requests From the Torque Rod Interface**
- **Acceptance Criteria: Confirm Proper Interface Behavior Over Long Periods of Time. Compare Flight Software Calculated Attitude and Rates to Injected Simulated Data. Verify Proper Response of Flight Software to Invalid Magnetometer Data. Verify Proper Response of Flight Software to Flight (and Engineering ?) Sensor Data**

Observatory Functions - Fine Balance & Trim

- **Tests: Verify Hardware and Software Interfaces to the Balance (Mass) and Trim (Area & Tabs) Actuators Are Working Properly**
- **Calibration: Collect Instrument Derived Attitude and Rate Responses to Balance and Trim Device Movement**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF) Command and Telemetry**
- **Stimulus Range:**
  - **Use Fine (Instrument) Attitude and Rate Information to Fine Balance and Trim Functions on Orbit**
- **Data Acquisition: Spacecraft Telemetry Indicating Actuator Interface Status and Spacecraft Attitude. All Resulting Unbinned/Engineering Interface Data**
- **Acceptance Criteria: Confirm Proper Interface Behavior Over Long Periods of Time**

Observatory Functions - Fine Attitude/Rate Propagation

- Tests: Verify Attitude/rate Propagation Model Is Correctly Implemented
- Calibration: Measure Attitude/rate Propagation Model Against Spacecraft Motion
- Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF) Command and Telemetry
- Stimulus Range:
  - Inject a Representative Set of Appropriate Guide Star Unbinned Images to Match Propagation Model
  - Inject a Representative Set of Matching “Science” Stars That Will Match the Propagation Model
  - Inject a Sample Set of Inappropriate Guide Star Unbinned Images That Will Not Match the Propagation Model
  - Collect On-Orbit Data
- Data Acquisition: Spacecraft Telemetry Indicating Status of the Attitude/rate Propagation Model. All Resulting Binned and Unbinned/Engineering Interface Data
- Acceptance Criteria: Confirm Propagated Attitude and Rate Solutions Are Within the Acceptable Accuracy Range

Observatory Functions - Science Data Collection

- **Tests: Verify Proper Science Data Collection Is Performed Using Fine Attitude Knowledge and Propagated Attitude**
- **Calibration: None**
- **Interfaces Utilized: Instrument Command (TDI Rate), CCX/AP IF Controller (Control IF), CCX/AP IF Controller (Unbinned/Engineering Data IF). Command and Telemetry**
- **Stimulus Range:**
  - **Inject a Representative Set of Stars That Initially Match the Attitude/rate Knowledge**
  - **Introduce Variances of Attitude and Rates**
  - **Inject a Representative Set of Stars That Do Not Match Attitude/rate Knowledge**
- **Data Acquisition: All Resulting Binned and Unbinned/Engineering Interface Data. Command and Telemetry**
- **Acceptance Criteria: Confirm Proper Collection of Binned and Unbinned Data. Verify FSW Reacts Correctly to the Attitude and Rate Variances. Verify FSW Reacts Correctly to the Unexpected Data**

Observatory Functions - Star Catalog Maintenance

- **Tests: Verify Proper Operation of the Star Catalog Maintenance Functions**
- **Calibration: None**
- **Interfaces Utilized: Command and Telemetry**
- **Stimulus Range:**
  - **Full Catalog Load**
  - **Catalog Verification Request**
  - **Catalog Dump Request**
  - **Catalog Update Request**
    - **Modify Observation Characteristics**
    - **Delete/Load a Tile**
    - **Add/Change/Delete Dynamic Observations**
    - **Control the High Observation Density Filtering Selection Criteria**
- **Data Acquisition: Spacecraft Telemetry Indicating Correct Response to Catalog Maintenance Functions**
- **Acceptance Criteria: Confirm Proper Operation of the Catalog Maintenance Functions**